



Research on the Batch Production Process Planning Problem of Assembly Line Based on the Virtual Enterprises

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Abstract: This paper analyzes the characteristics of the assembly line production system of Virtual Enterprises, and proposes production structure model of assembly line based on the optimization techniques of time superposition. The model considers the regional distribution of Virtual Enterprises and the resulting of transportation costs, stock costs and processing costs of the time constraint, and proposes the optimization scheme based on genetic algorithm. The results of experiment showed that this model could calculate the minimize costs of production, which meet the constraints of total duration.

Keywords: Streaming-flow Production; Virtual Enterprises; Process Planning.

1. Introduction

Assembly line production applied a series of production methods, which involves the use of general equipment to make each task of assembly line have stable cycle time and enable the material flow from one node to the next node in the internal of enterprises quickly and smoothly, according to the order of processing operations. While technical or manufacturing resource conflicts appear and individual enterprise can't independently fulfill the orders on schedule, it is necessary to set up virtual enterprises in combination with other partners. Materials is produced and flow among the virtual enterprise members according to a particular logical sequence, the calculation of the order period involves the time-consuming of each node to complete the processing(assembly), and the time of material transportation between each node; the calculation of the order costs is related to the processing(assembly) costs, inventory costs and material transportation costs of each node; How to select enterprise member of each node and how to plan the logistics of virtual production flow line reasonably, is a core problem of virtual enterprise streamline production which needs to be solved urgently.

Lot –streaming Flow shop Scheduling Problem (LFSP) is a typical NP-hard issues, which has a wide range of engineering application background [1]. At present, the research on this kind of problem had attracted extensive attention world widely. Document[2] analyzed the principle and characteristics of virtual assembly line production system, and at the same time studied the load balance of assignments of virtual assembly line production and application problems of just-in-time production control technology. Document [3] aimed at

assembly enterprises having small batch and multispecies order, designed formation program of assembly line, which shortened the production period and improved the production efficiency. Document[4] aimed at Lot –streaming Flow shop Scheduling Problem and put forwarded an improved artificial bee colony algorithm to optimize the maximum completion time, and the algorithm uses the NEH method to generate the initial solution, then generate a new neighborhood solution in the chaos traverse method. Document[5] studied the resources scheduling problem of the virtual enterprise assembly line in conditions of incomplete information, and proposed the optimized scheduling scheme of the tender results by combining network tender and genetic algorithm. In summary, the main problem lies in the background of single enterprise, and the model only considers the order duration, not considering the regional characteristics of the production line in the virtual enterprise and the resulting of transportation costs and inventory costs. This paper first analyzes the production period and the method of cost calculation of the virtual enterprise assembly line, proposing a production process planning model, and finally applies the optimization algorithm for solving.

2. Calculation and analysis on order duration and cost of production of virtual enterprise assembly line

Assuming that the leader of an alliance accepts orders for the M sets of products, the total duration is SD , each production requires N production process of assembly line, a total of K ($K \gg N$) leaguers enterprises can provide processing services, for example, we select N enterprises who are respectively responsible for N process, in order to shorten the production period, all participating companies

produce in JIT (Just In Time) method. once continuous production starts, the production of assembly line is shown in **Figure 1**, k_i means the number of enterprise who is responsible for the i -th procedure, and enterprise k_i implement the i -th procedure consuming time of $TT(k_i)$, the cost of which(assembly)is $AC(k_i)$ and the inventory costs of unit time is $PSC(k_i)$, time - consuming of the workpiece from the previous node enterprises k_{i-1} transport to node k_i is $ST(k_i)$, then the order of duration and cost is calculated as follows:

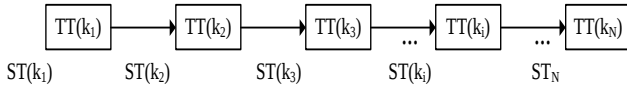


Figure 1. A traditional virtual enterprises production line chart

$$ST(k_i) = \begin{cases} 0 & i = 1 \\ D(k_{i-1}, k_i) / v & i = 2, 3, \dots, N-1 \end{cases}$$

Among $D(k_{i-1}, k_i)$ Represents the distance between the enterprise responsible for the $i-1$ and i node processes, and v is the speed of vehicle transport. The total duration of the order DT and the total cost of $SumC$ are calculated in this way:

$$DT = \sum_{i=1}^N [ST(k_i) + TT(k_i)] + (N-1) * MAX(ST(k_i) + TT(k_i)) \quad (1)$$

$$SumC = N * \left[\sum_{i=1}^N AC(k_i) + \sum_{i=2}^N D(k_{i-1}, k_i) * DC \right] + (N-1) * \left\{ \sum_{i=1}^{N-1} [TT(k_{i+1}) - TT(k_i) - D(k_{i-1}, k_i) / V] * PSC(k_i) \right\} \quad (2)$$

Among them: DC is the consumption cost of unit mileage of work piece truck, and sum is the total costs of order which involve node processing costs, transportation costs and inventory costs. When the second set of products start to be produced, it is bounded to have a part of inventory and equipment idle and make the result of an extension of time taking into account the time-consuming of the various processes ranging and work piece transport. In addition, it produce the inventory costs (unit inventory costs * inventory time). Storage time is calculated as the difference time of two nodes processes minus transit time.

Clearly, this traditional assembly line production has long logistics operation duration and big inventory costs, which is

difficult to respond to rapid market demands. In order to speed up the efficiency of logistics operation, this thesis based on time overlap optimization techniques of the traditional assembly line reconstructs the production process in **Figure 2**, increasing the processing enterprises in the processing of more time consuming nodes and making true on the work piece parallel circulation to shorten the logistics of running time and inventory costs. The specific methods list as follows:

Setting $T = \min(TT_i)$, which means the minimum

time-consuming through all assembly nodes for T , then the other nodes needed to increase the number of processing

enterprises which is $L_i = \text{Int}(TT_i / T) + 1$, after refactoring

the production process structure is shown in **Figure 2**;

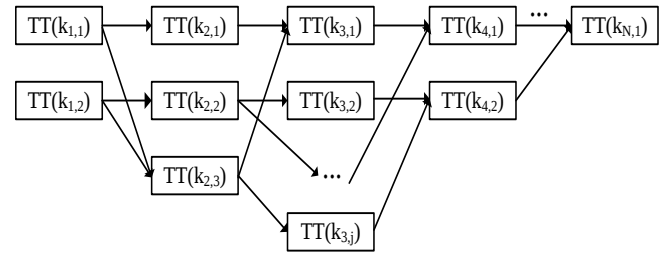


Figure 2. Production line chart based on the time overlap optimization technology

In this mode, several companies are probably capable of processing the procedure, the processing tasks in a node of different product can be parallelly produced by different enterprise, shortening the total duration; considering comprehensively of the processing costs, transportation costs and inventory costs of each node production unit, it can reduce the total costs. Assume that m denotes the number of the entire product, i represents the processing operation number, j represents the business number, if firm j has the capacity to process the process i , the $F(i, j) = 1$, otherwise $F(i, j) = 0$; if the products of m 's i -th process is completed by the j -th enterprise, $S(m, i, j) = 1$; otherwise $S(m, i, j) = 0$. $TT_{i,j}$ represents enterprise j 's Time-consuming to process i process, $AC_{i,j}$ said processing costs. Duration DT to complete the M sets of product orders computable as follows:

$$DT = M * T + \sum_{i=MI+1}^N \sum_{j=1}^J [TT_{i,j} * S(M, i, j)] + \sum_{i=MI+1}^N \sum_{j,k=1}^J D(k, j) * s(M, i, j) * s(M, i+1, j) / v \quad (3)$$

Among them: the values of MI is smallest hours of the process ID,J is the total number of enterprises, D () is said as the distance between the previous enterprises and the next enterprises commitment to a final set of products, v is the average speed of transport the processing workpiece.T

The total cost of order SumC involved processing costs PC, transportation costs TC and inventory costs SC can be calculated as follows:

$$PC = \sum_{m=1}^M \sum_{i=1}^N AC_{i,j} * s(M, i+1, j) \quad (4)$$

$$TC = \sum_{m=1}^M \sum_{i=1}^N \sum_{j,k=1}^{IJ} D(k, j) * s(m, i, j) * DC \quad (5)$$

Where:DC is consumption costs of per unit distance of workpiece transport vehicles .

The calculation of inventory costing is more complex,which related to the time ET that transport the workpiece to a node and the time BT that start time of node enterprises . The calculation steps are as follows:

Seep1: The calculation of ET and BT of processing enterprises on the first equipment.

When m = 1, the point in time of workpiece transported to the node equal to the point in time of actually start working, will not have inventory costs, due to the processing enterprises have not officially started.

When n = 1:

$$ET_1(1) = BT_1(1) = 0$$

When n>=2

$$ET_1(n) = BT_1(n) = \sum_{j,k=1}^J \sum_{i=1}^{n-1} [TT_{i,j} + D(k, j) / v] * s(1, i, j)$$

$$n=2 \dots N \quad (6)$$

After any one procedure of the first product is completed, the completed time points of enterprises j BTE as follows:

$$BTE(j) = ET_1(n-1) + TT_{n,j} * s(1, n, j)$$

$$n = MAX(i) \{s(1, i, j) = 1\}$$

In the top equation, N is the last process node of enterprise j involved in the production:

Step2: Calculate ET and BT of the follow-up processing equipment m (m> = 2).

When n=1:

$$ET_m(1) = BT_m(1) = \sum_{j=1}^J s(m, 1, j) * BTE(j) \quad (7)$$

When n>=2

$$ET_m(n) = \sum_{i=1}^{n-1} \sum_{j,k=1}^J [ET_m(i) + D(k, j)] * s(m, i, j) \quad (8)$$

Step 3: At this point the M sets of products after the start time of N nodes, the time of transportation to the nodes have been calculated, and inventory costs can calculated as follows:

$$SC = \sum_{m=1}^M \sum_{i=2}^N [ET_m(i) - BT_m(i) * psc(m, i, j)] \quad (9)$$

Among them:psc(m,i,j) is the unit inventory costs of the m products in the i-th processing produced by firm j .

Total cost $SumC = PC + TC + SC$, the problem is transformed into how to choose the processing enterprises of nodes, under the premise of ensuring the total duration of SD, can minimize the total cost? The mathematical model can be expressed as:

$$Min(SumC) = \min(PC + TC + SC) \quad (10)$$

$$ST:(1) \quad \forall i, \quad \sum_{j=1}^J f(i, j) \geq 1 \quad \text{Any process at least}$$

completed by an enterprise who has ability to complete the processing tasks. (11)

$$(2) \quad \forall m, \forall i \quad \sum_{j=1}^J s(m, i, j) = 1 \quad \text{Each process of}$$

each product can only be done by an enterprise. (12)

$$(3) \quad DT \leq SD \quad \text{Satisfied the total duration requirements} \quad (13)$$

3. Optimization solution of virtual enterprise assembly line production process

Genetic Algorithm (GA),is a simple and efficient combinatorial optimization algorithm and a global optimization method based on the principle of natural evolution and natural genetic, is widely used in many engineering and optimization problems. This paper uses genetic algorithm for assembly line production process of virtual enterprise optimization problem in this way as follows:

(1)Gene encoding

The production process of virtual enterprise depends on the choice of processing enterprises on each node in the production structure diagram, and the enterprise of the model is natural-number coded shown in **Figure 3**:

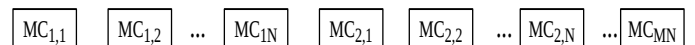


Figure 3. Chromosomal gene encoding

In **figure 3**, $MC_{i,j}$ means the number of processing enterprises who produce the i sets of product and j -th procedure, the length of the chromosome as $M * N$.

(2) Chromosomal gene swap position

The purpose of swap position is to obtain the optimal combination of virtual enterprises production lines, the optimal solution quickly and the crossover operator: The purpose of swap position is to obtain the optimal combination of manufacturing resources, in order to obtain the optimal solution quickly, this paper designed single parents, parents-based crossover operator. The parents include: cross-point, block cross and half-and-half cross. Point-to-point cross refers to the number of points corresponding to cross, block cross refers to a range of chromosome cross and half cross refers to any point (gene) of the chromosome, all the genes behind the gene cross. Shown in **figure 3**:



Figure 3 (a). Single gene crossover operator

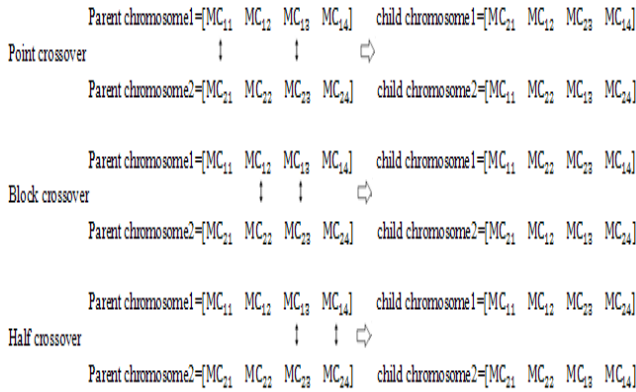


Figure 3 (b) Parental genetic crossover operator

Each chromosome in the population were randomly assigned a probability, which is less than the crossover probability PC chromosome collection (typical crossover probability P_c , the range of 0.6 to 1.0), and point cross, block cross and half cross are implemented in paired.

(3) Detection and evaluation of chromosome

The initial chromosome turned into a number of chromosomes sets after gene transposition, some of which become good varieties, and the other part may be infeasible solution, so test and evaluation of the feasibility of the chromosome is needed, discarding infeasible solutions and making superior varieties become the next generation of population.

First detecting chromosomes based on formulas (11) and (12) in section 2 whether they meet the constraint conditions (1) and (2), if not satisfied, the chromosomes which are infeasible solutions are discarded; Then calculate the total duration DT according to the formula (3), chromosome is feasible solution

if DT satisfies the constraints 3 (Equation 13), otherwise discard.

With feasible solution, according to formula (4) and (5) we can calculate processing and transportation costs, and according to the formula (6) - (9) inventory costs can be calculated, finally gain the total cost $SumC$.

(4) Accordance the principle of the total cost from small to large, sorting chromosome and selecting the minimum cost of chromosomes as the new population and go to step (2) ...

Repeat several times, we can get the optimal solution of the production process.

4. Experimental Analysis

The customer needs 10 sets of equipment, all the work should be done in 16 days, each set of equipment requires four processes (assembly lines), **Table 1** shows the serial number of enterprise, which offer services, hours of work, assemble costs, inventory costs and the physical coordinates of the location, what each process can provide.

Table 1. Production information of the related virtual enterprise

number of enterprise (x,y)	processes 1	processes 2	processes 3	processes 4
1 (55,172)	(1.3,210,30)			
2 (68,168)		(2.8,260,50)	(1.5,550,100)	
3 (60,180)	(1.4,200,40)			
4 (73,170)		(2.9,250,40)		
5 (75,175)			(1.6,540,90)	
6 (82,172)	(1.1,260,20)		(1.7,530,70)	
7 (75,168)		(2.3,300,80)	(1.7,520,75)	
8 (73,160)		(2.4,280,70)	(1.8,510,60)	
9 (80,162)	(1.2,240,30)			(1.2,200,30)
10 (68,170)		(2.7,270,60)		(1,180,20)

The meaning of the data in **Table 1**, 1 (55,172) means the serial number of the enterprise is 1, and its geographical coordinates is (55,172), (1.3, 210, 30) means the first enterprise cost 210 in finishing the first process during 1.3 hours, and inventory cost in per unit time is 30, here we assume superior supplier manages the inventory. How to select the processing enterprises for each process node in every set of equipment, we conclude the solution process as follow.

Step (1) : Construct the initial chromosome

According to the serial number of the enterprise and process order in **Table 1** to select the processing enterprises, thus we can get four initial chromosomes which is shown in **Table 2**.

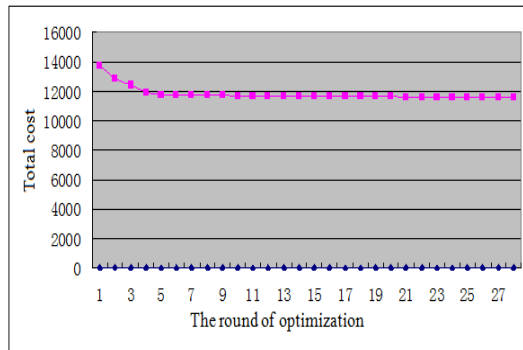
Table 2. The initial chromosome

1	2	2	9	3	4	5	10	6	7	7	9	9	8	8	10	1	10	2	9	3	4	5	9	6	7	7	9	9	8	8	9	1	10	5	9	3	2	2	10
3	2	6	9	3	4	5	10	3	2	6	10	3	8	6	10	3	4	6	9	3	2	5	10	3	4	6	10	3	2	6	10	3	4	6	10	3	2	6	9
6	7	7	9	9	8	8	9	1	2	2	9	3	4	5	9	6	4	5	10	3	2	8	10	3	2	8	10	3	4	7	10	3	8	8	10	3	4	7	9
9	8	7	10	1	4	2	10	3	2	7	10	1	8	2	10	3	4	7	10	1	2	2	10	3	8	7	9	1	4	2	10	3	2	7	9	1	8	2	10

Step (2) : Implement step (2), (3), (4), including in step 3, to initial Chromosome, after 27 iterations operations, finally we can get the optimal solution ultimately:

3 4 7 10 3 8 8 10 3 2 7 10 3 4 8 10 3 4 8 10 3 2 8 10 3 2 7 10 3 4 7 10 3 2 7 10 3 4 8 10

The production period is 16 days, which satisfy the constraints, and the total cost is 11529. The figure of enterprise's assembly line production structure is 1 (3) - 3 (4, 8, 2) - 2 (7, 8) -10, that is, process 1 completed by the enterprise 3, process2 completed by enterprises 4,8,27, process 3 completed by the enterprise 7, 8, process 4 completed by the enterprises 10, the analysis results are consistent with what concluded in section 2 of this article, the optimal solution of each round shown in **Figure 4**

**Figure 4.** The optimal solution of each round

5. Conclusion

Production by assembly line is the traditional modes of production in the enterprise's internal manufacturing. Along with the development of Internet technology and the rise of virtual enterprise collaborative modes of production, the course about assembly line production process planning restricting the production of virtual enterprise, become the critical problem. This paper considers the regional distribution of Virtual Enterprises, the result of transportation costs, stock cost and processing costs of the time constraint, propose the Optimization scheme, which bases on genetic algorithm, and also verify the feasibility and effectiveness of the model by the experimental analysis of the model.

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